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FALLOUT PROTECTION for HOSPITALS

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

PUBLIC HEALTH SERVICE

A HILL-BURTON PROGRAM ACTIVITY

FALLOUT PROTECTION FOR HOSPITALS

Prepared by

Architectural and Engineering Branch
Division of Hospital and Medical Facilities
Public Health Service

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Washington 25, D.C.

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FOREWORD

This is a report of studies conducted to develop principles for the design of hospitals offering protection from the effects of gamma radiation resulting from fallout of a nuclear explosion. The methods of protection from chemical and biological contaminants and from a moderate degree of blast overpressure were also investigated, and the cost of such protection is included.

The studies revealed the feasibility of incorporating special measures to protect patients, personnel, and vital functional components within the facility. Moreover, it was found that such construction could be carried out at a reasonable cost.

This project, an activity of the Hill-Burton Program of the Public Health Service, was developed under a grant from the Office of Civil and Defense Mobilization, now the Office of Civil Defense, Department of Defense.

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FEBRUARY 1962.

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INTRODUCTION

In keeping with its responsibility for protecting and improving the health of the people of the Nation, the Public Health Service has, for many years, been interested in the problems which would face the Nation's hospitals in the event of a nuclear disaster. In addition to sheltering its occupants, the hospital should do its utmost to preserve its basic services and facilities for prompt use after the disaster period. Efficient hospital service is an important adjunct to the rapid recovery and rehabilitation of a disaster-struck community, especially following a nuclear attack.

The detonation of a nuclear weapon produces four major effects—blast, heat, initial nuclear radiation, and residual radioactivity due to fallout. The first three effects will be limited to an area surrounding the immediate vicinity of the detonation. The fourth, however, could affect practically the total population of the country.

The National Shelter Policy, announced by the Office of Civil and Defense Administration in 1958, states: "The Administration has conducted exhaustive studies and tests with respect to protective measures to safeguard our citizens against the effects of nuclear weapons. These several analyses have indicated that there is a great potential for the saving of life by fallout shelters. In the event of nuclear attack on this country, fallout shelters offer the best single nonmilitary defense measure for the protection of the greatest number of our people.

"The Administration's national civil defense policy, which now includes planning for the movement of people from target areas if time permits, will now also include the use of shelters to provide protection from radioactive fallout."

To implement this established policy, the Public Health Service has collaborated with the Office of Civil and Defense Mobilization to develop criteria and standards for protective measures in hospitals.

GENERAL CONSIDERATIONS

A hospital having a 150-bed capacity was selected as a basis for study in this research project for two principal reasons. First, this was agreed to be the optimum size to illustrate the complex problems of departmental relationship and hospital communications in conjunction with the essential features of civil defense protection without obscuring the obvious characteristics of either. The results of this study could easily be used by designers of larger or smaller hospital facilities with minimum adaptation and interpolation. Second, a hospital of this capacity appears to be typical of the size likely to be built outside the periphery of an urban community or in the environs of a potential target area. Because of its location, this hospital would be spared the destructive effects of blast and heat but could be subject to the effects of fallout radiation.

The following broad guidelines were established to assist in the development of the project:

(1) *The hospital should be designed to function as a normally planned hospital.* The hospital should be designed to operate in a conventional manner as a 150-bed hospital fulfilling the specific needs of an average community. The size and importance of its various departments would vary with the needs of the community in which it is to be built. The plan, both in overall pattern and details, should reflect the best current thinking in hospital design. It should be recognizable as a good hospital plan whether the hospital is built with or without the protective features.

(2) *The protective measures should be incorporated in the plan in a manner that will least impair the normal functional aspects of the hospital design.* Every effort should be made to provide an efficient and economical facility, from the point of view of day-to-day operations, of such design and construction that the civil defense requirements do not adversely affect hospital functions. The resulting design should be useful as a guide for planning hospitals with varying degrees of protection from maximum to minimum, depending upon the community's civil defense program.

(3) *Consideration should be given to the maximum utilization of available hospital services for shelter purposes.* The greatest economy in design and construction, it is believed, would be effected if the space and equipment provided exclusively for civil defense purposes are kept to a minimum. All suitable space in the protected area should be considered available for shelter use during the emergency period. If the equipment vital to the operation of the shelter is used in the normal operation of the hospital, its reliability would be of a high order.

(4) *The plan should meet the basic requirements of current building codes.* Unless recommended criteria and standards resulting from this study are compatible with today's up-to-date building codes and regulations, it may be difficult, if not impossible, to use them on active building projects. This implies that the nursing units should not be placed in a windowless structure since present codes do not permit a patient room to be so located. Similarly, exit facilities, mechanical equipment, and other such considerations should comply with functional hospital practice when the structure is in everyday use.

(5) *If possible, the protective features of the resulting plan should be readily apparent.* Since this project is to serve as a prototype, the civil defense aspects should be well defined and easily assimilated.

(6) *The plan and the exterior design should be as up-to-date and as attractive as possible.* Attention should be directed toward making this project appear to be as conventional as possible. Wholehearted acceptance and use by the community might be jeopardized if the resulting structure were to be significantly different from standard construction.

THE HOSPITAL PLAN

The hospital is basically a single-story structure joined to a four-story wing by a vertical shaft that contains the elevators and connecting corridors. A full basement is provided.

The single-story unit is the protected unit. It is windowless and is planned with a minimum number of openings. Only those hospital elements whose function or use would not be jeopardized in any manner by being located in a windowless environment are contained in this unit. On the first floor, it houses the delivery suite, surgical suite, X-ray department, pharmacy, laboratory, physical therapy department, and outpatient facilities. The concept of placing such clinical and diagnostic areas in a windowless structure has been widely accepted. The basement or ground-floor level contains dietary services, laundry, central sterilizing and supply areas, storage rooms, and the autopsy suite. These services, it should be noted, are frequently located in the basement or underground portions of hospital buildings with limited access to an exterior wall opening.

The only unusual planning deviation for the protected unit is the provision for ventilation. Fresh air is provided for the protected unit by means of an isolated air-intake tower located at a distance from the building, to ac-

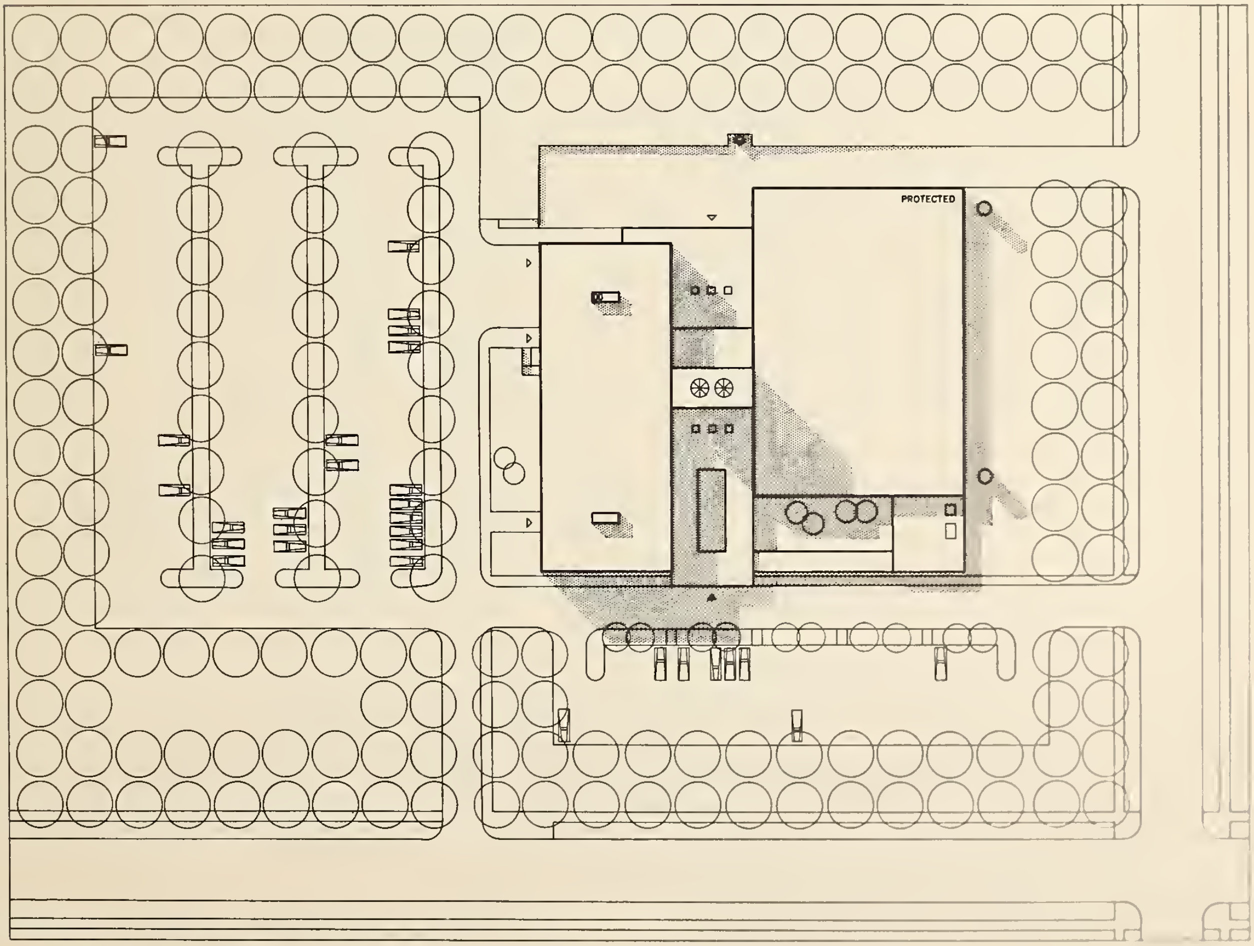
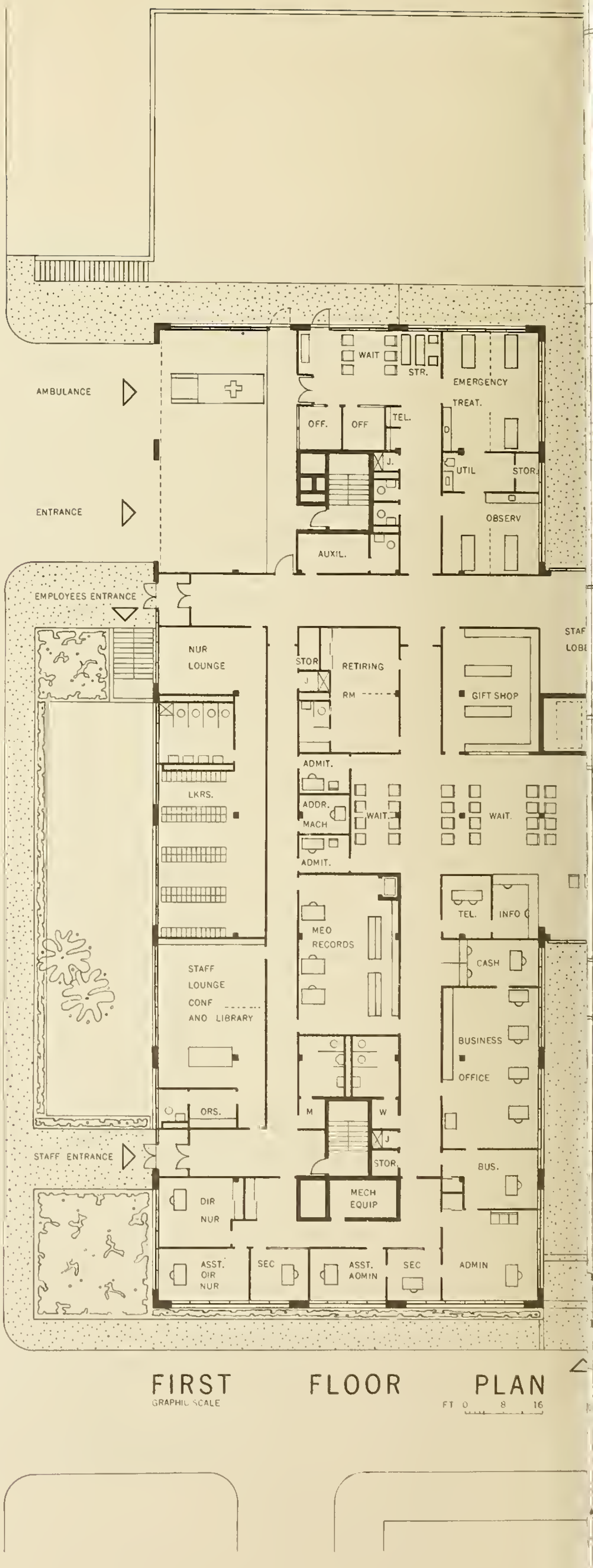


Figure 1.—Site plan.

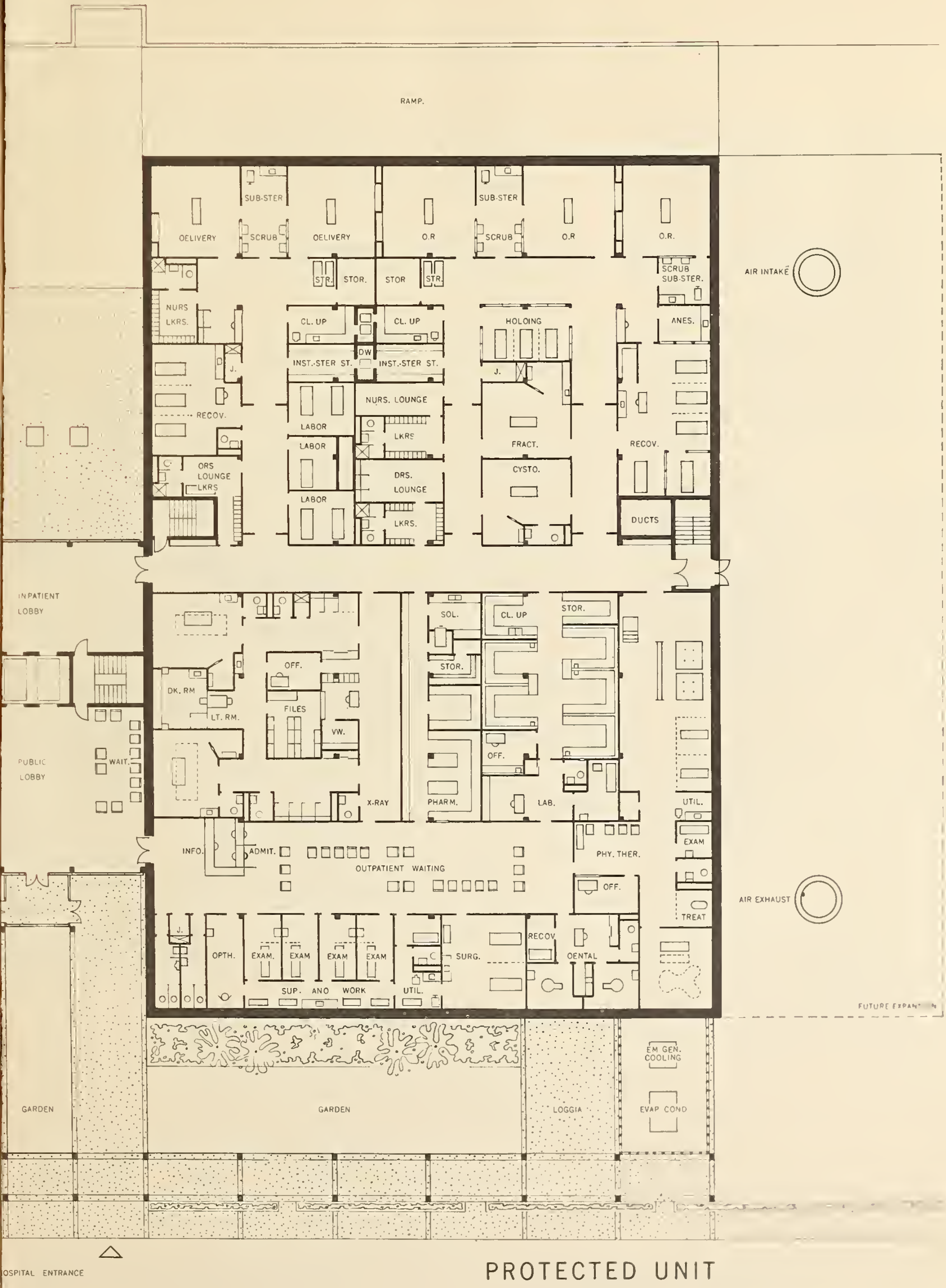
Figure 2.—First-floor plan.



commodate the necessary air-cleaning devices. Similarly, an air-exhaust tower is used to minimize the number of openings in the exterior walls. It might have been feasible to locate the air-intake and air-exhaust stacks contiguous to the exterior walls, but it was considered architecturally desirable to set them away from the buildings. To minimize air pollution, these stacks are isolated from each other as much as possible.

The multistory wing and the elevator shaft are planned to be of conventional construction. The first floor contains the main entrance lobby, the administration department, staff doctors' and nurses' facilities, and the emergency department, all conveniently accessible from the street and parking area. The ground floor contains the service entrance, employees' facilities, boiler room, maintenance shops, and locker room, while the upper floors house all the nursing units. As mentioned previously, current building codes contain restrictions against windowless patient rooms. This is the prime reason for locating the nursing units in the unprotected wing of the hospital. Moreover, at this time, there is a widespread public dislike of windowless patient rooms. Therefore, since it was possible to provide adequate shelter space without using the patient areas, this was done.

For shielding purposes, the number of openings into the protected unit is limited to the minimum needed for functional use. On the first floor is a public entrance to the outpatient department with ready access to X-ray, pharmacy, laboratory, and physical therapy. Another entrance provides access for inpatients, outpatients, and staff to the clinical services. This floor also contains an exit door for use in case of fire.



PROTECTED UNIT

The ground floor has a public entrance to the dining facilities, a service entrance to the supply and housekeeping areas, and a separate door to the morgue and autopsy suite. The air-intake and air-exhaust openings also are located on this floor. During the period of the radiation fallout emergency, all main doors to the protected unit will be sealed and access and egress from the structure, if necessary, will be through the autopsy entrance. This is equipped with airlocks and suitable washing facilities for radiological decontamination of individuals who may have been subjected to the fallout environment.

The site plan is designed to separate service traffic from staff, employee, and visitor traffic. Convenient parking is provided for visitors near the main entrance, and if necessary, additional parking can be accommodated in the employees' and staff main parking area at the side. The judicious use of landscaping and tree plantings serves to minimize street noise and dust as well as improve the view for the hospital occupants.

Flexibility to permit expansion is another important consideration. The dotted lines on the plans indicate suitable directions for increasing the clinical and service departments; this construction may be protected or unprotected as deemed necessary. The surgical department could be expanded into the obstetrical area, which then could be relocated to the second floor of the protected unit along with an enlarged maternity and nursery department. Additional medical and surgical units could be constructed over the new obstetrical unit and the existing nursing units.

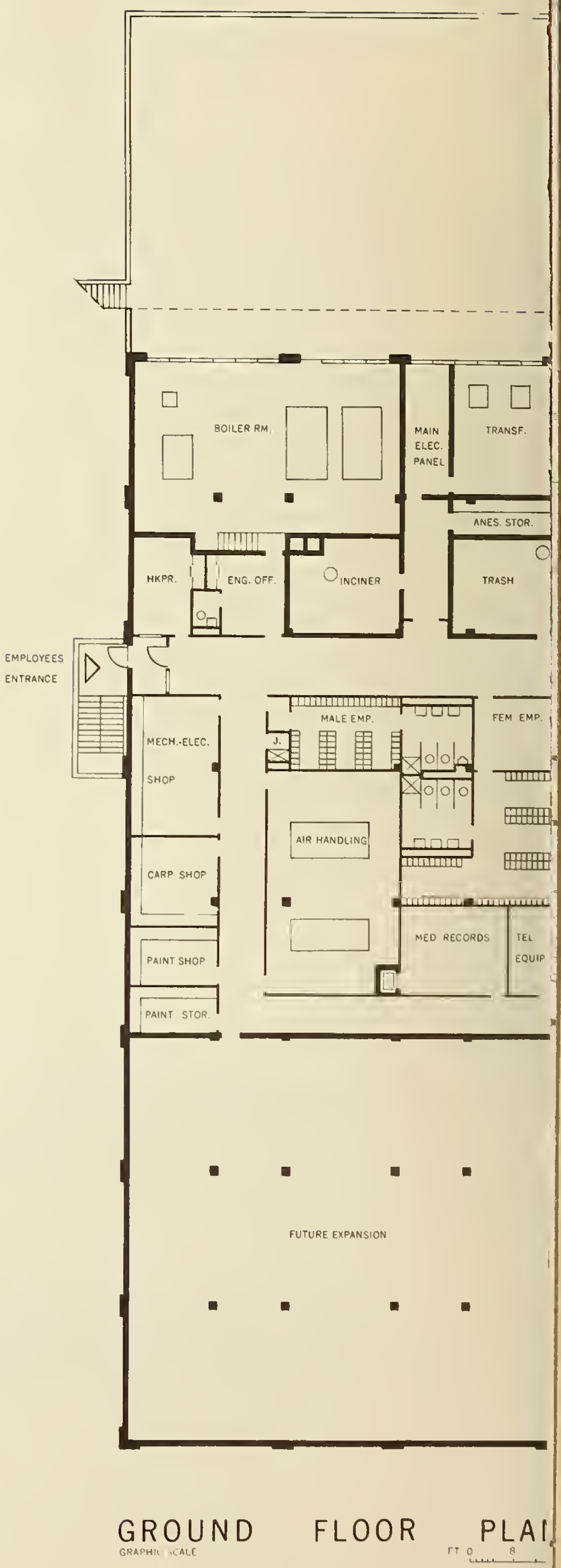
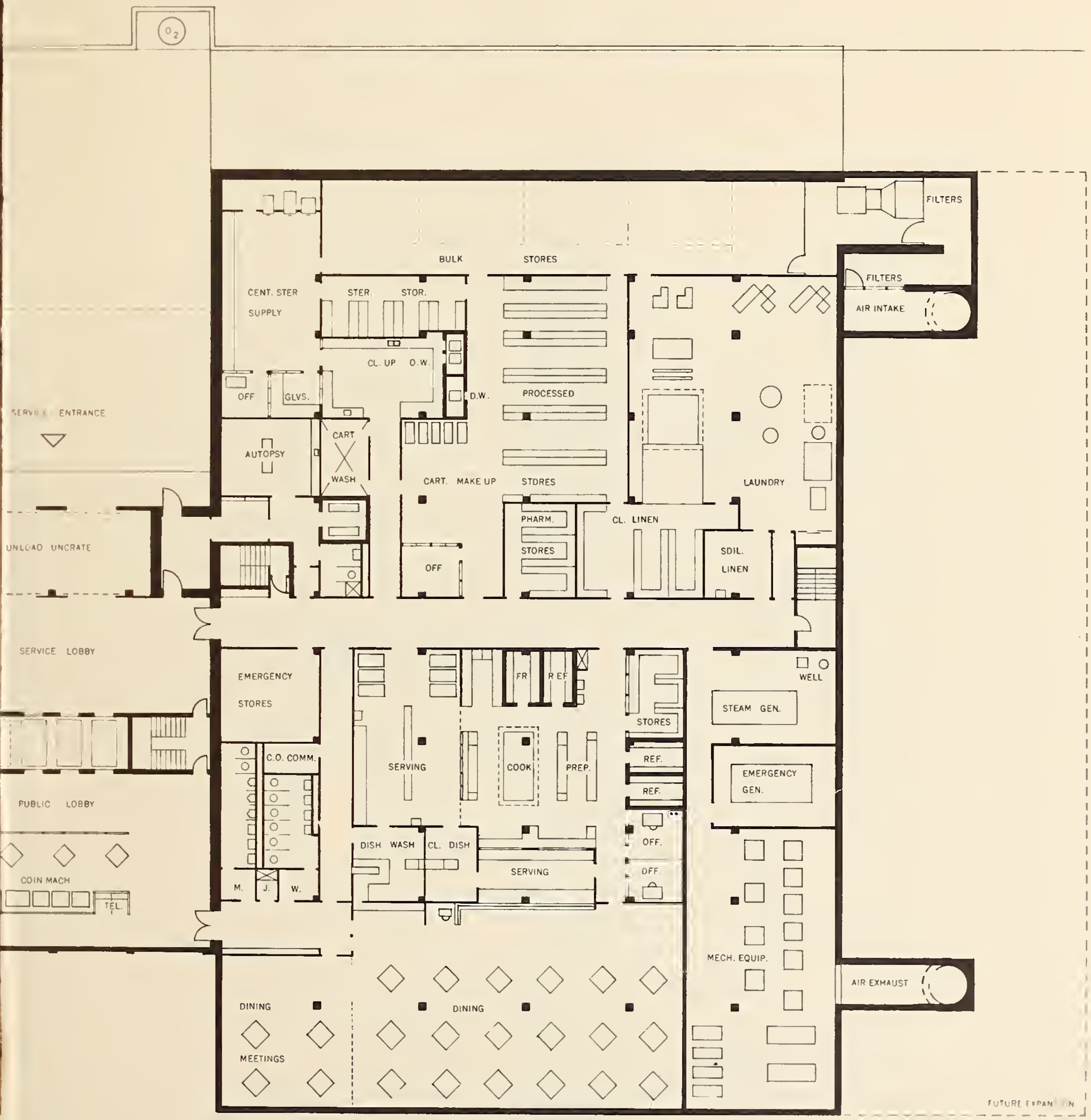


Figure 3.—Ground-floor plan.



PROTECTED UNIT

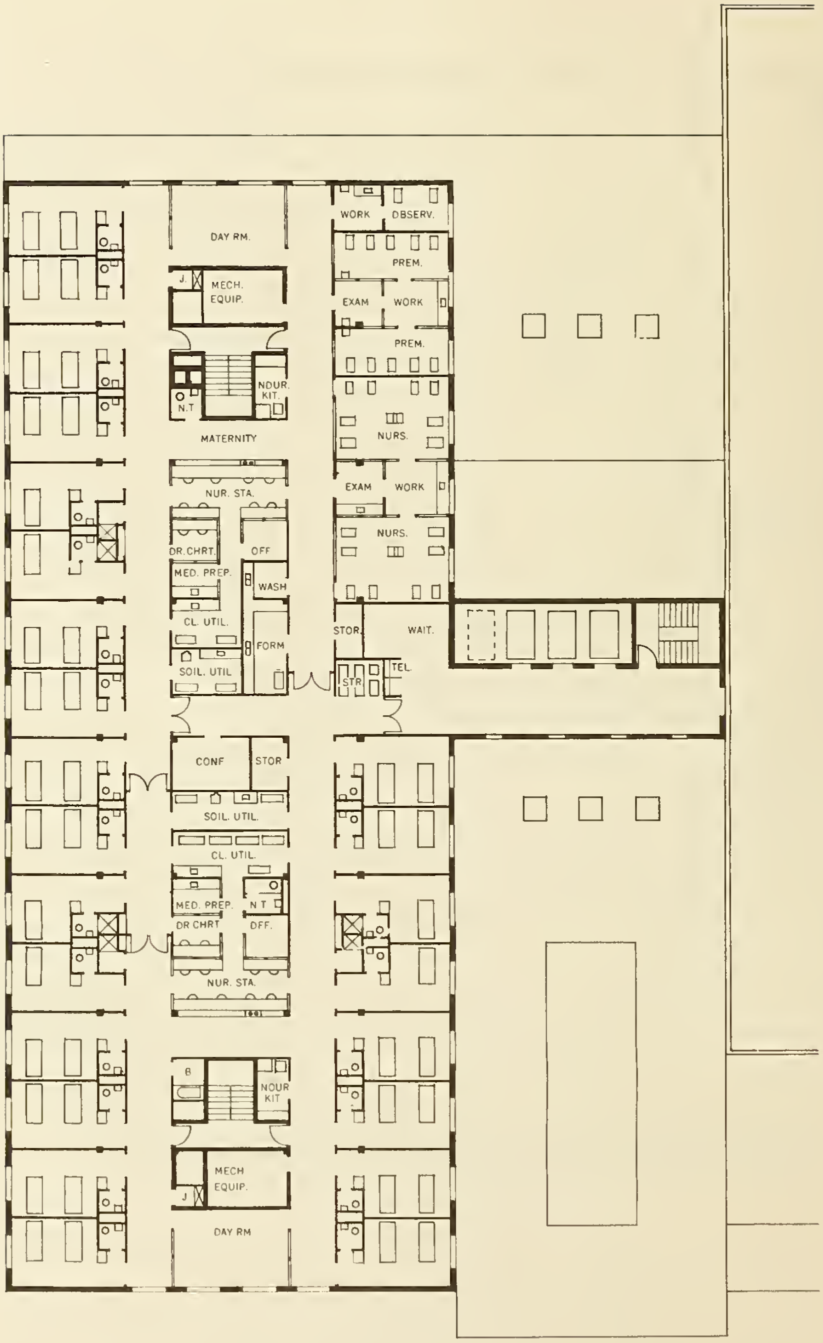


Figure 4.—Second-floor plan.

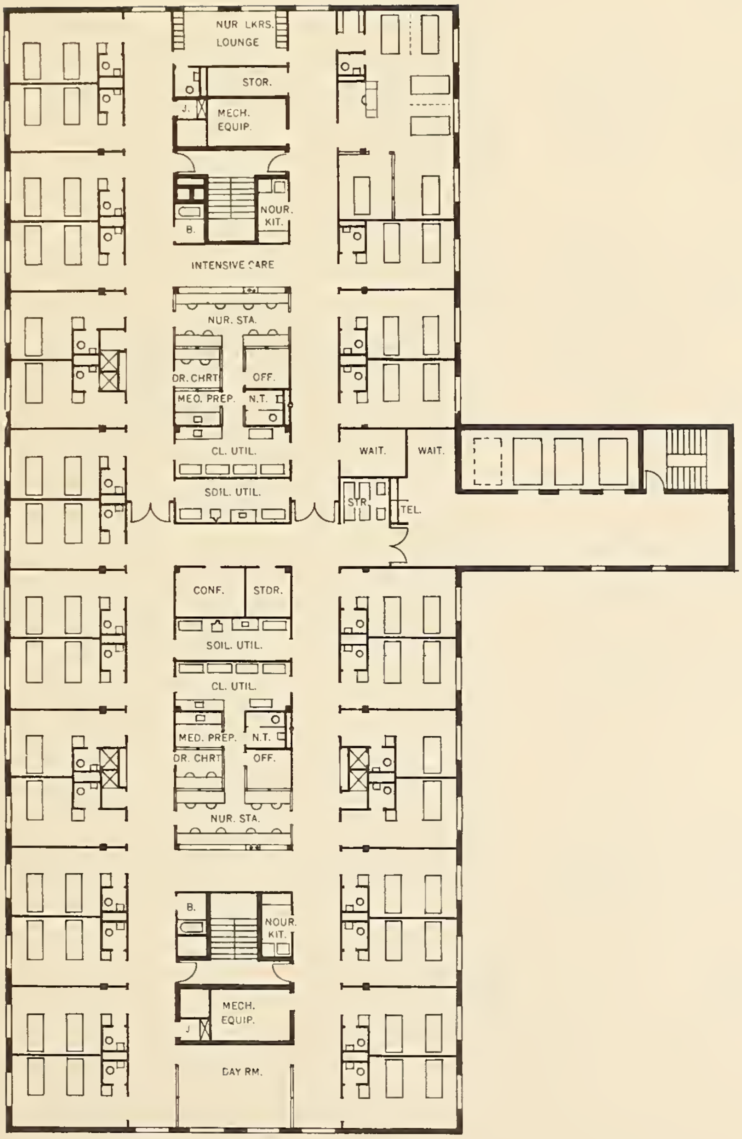


Figure 5.—Third-floor plan.

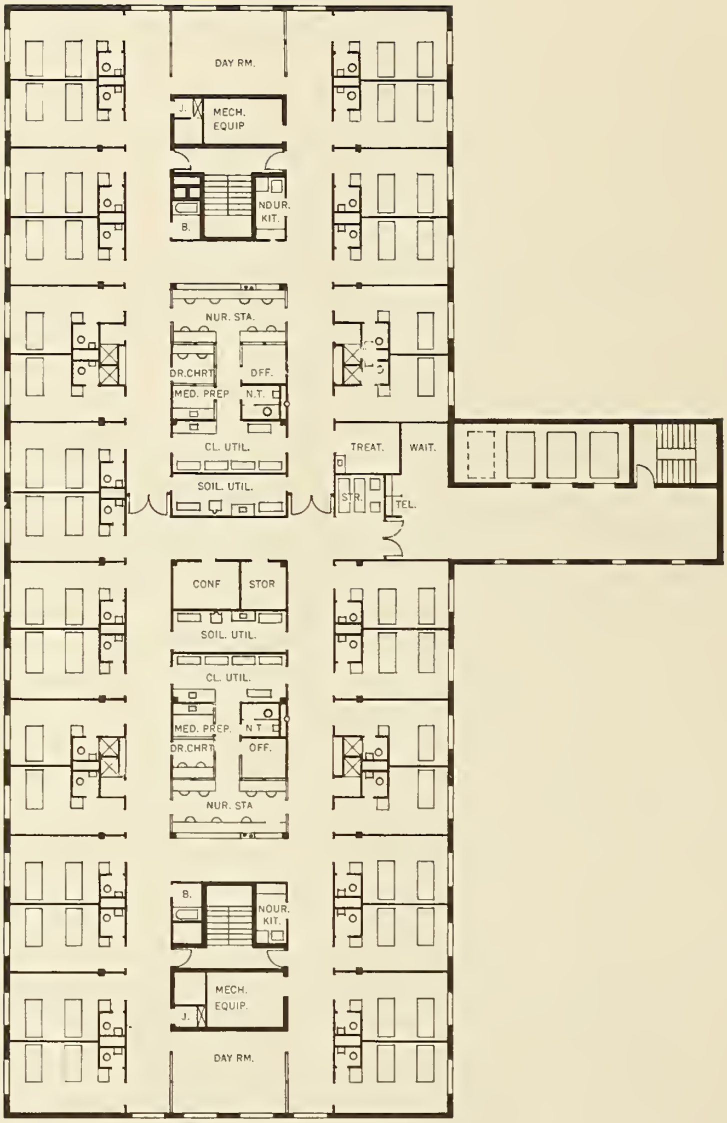


Figure 6.—Fourth-floor plan.

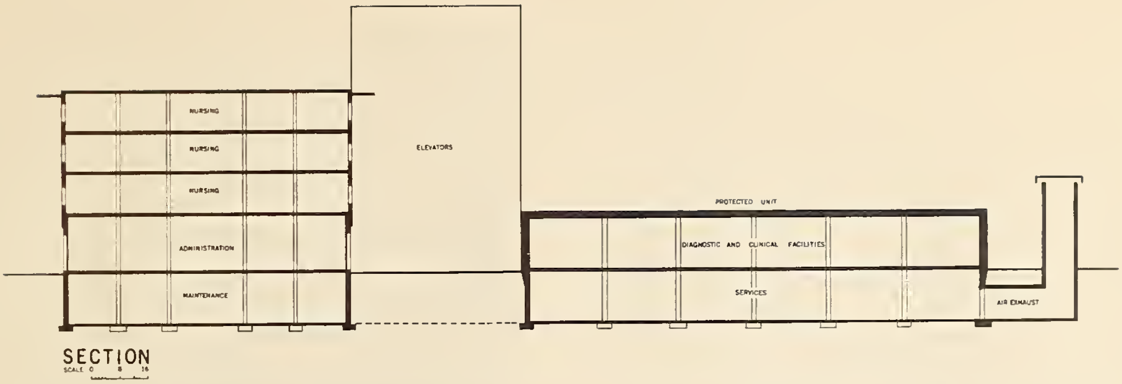


Figure 7.—Section of prototype hospital showing relationship of protected unit to nursing unit.

PLANNING ALTERNATIVES

In addition to the prototype plan shown, a number of alternative schemes were considered and were developed to various stages.

Alternative Scheme A (Fig. 8)

The protected unit can be located entirely underground, with the administration and nursing units directly above it. This is highly effective for minimizing radiation, but would require some compromise in functional planning. Although the shielding requirement for wall and roof construction of the protected unit could be satisfied with less material, the additional excavation and waterproofing required might increase the total cost to an amount equal to or more than the cost of the prototype.

Alternative Scheme B (Fig. 9)

Where the topography of the hospital site is uneven, it may be possible to set the protected unit into a hillside, thereby obtaining maximum shielding benefit from the natural ground.

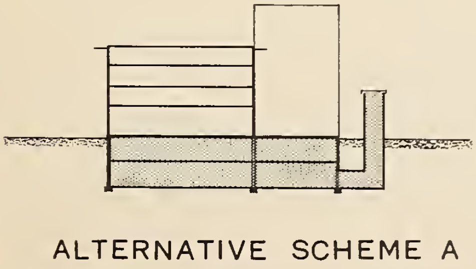


Figure 8.—Alternative scheme A: with protected unit underground.

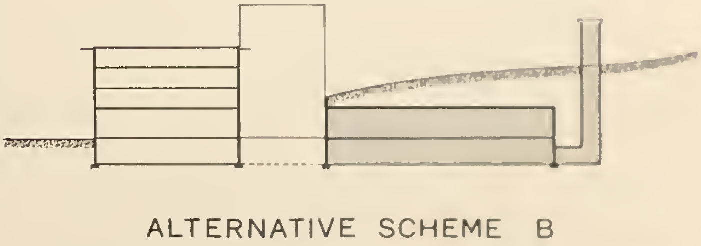


Figure 9.—Alternative scheme B: with protected unit in a hillside.

SHELTER SPACE

In the event of nuclear attack, under normal weather conditions, significant amounts of fallout do not arrive outside the blast area sooner than about one-half hour after the explosion. It is reasonable to assume, therefore, that a hospital located outside the blast area, if promptly notified of an attack, would have time to prepare for the fallout emergency.

Upon such warning, all patients, staff, and others in the unprotected wing of the hospital would be evacuated to the protected unit. Keyed, loose masonry blocks would be placed to seal the door openings. The mechanical and electrical systems would be switched on to the preplanned civil defense emergency operating conditions and cots would be set up to accommodate the number of persons to be sheltered. Based on current civil defense thinking, it is assumed that the fallout emergency may last as long as 2 weeks, and sufficient food, fuel, and other supplies should be stored for this interval.

Since an attack may occur at any time, the hospital should be prepared to act without delay and should be able to provide shelter accommodations at least for all individuals within the hospital at the time of the alert. The peak population of a 150-bed general hospital is estimated to be 363, as noted in figure 10, which gives an indication of the minimum accommodations that should be provided. The type of basic hospital plan selected would strongly influence the extent of the protected area that would be economically feasible. In this project, for example, by protecting the entire clinical-diagnostic service unit, it is possible to accommodate a total of about 750 persons at little extra cost over the amount required to provide protection for the minimum population. This additional capacity would be an important adjunct to the community's civil defense program by providing the accommodations to shelter more hospital and medical personnel as well as the public.

Department	24-hour population			Peak occupancy		
OPERATING STAFF	*Total*	*Male*	*Female*	*Total*	*Male*	*Female*
Administrative	20	4	16	18	3	15
X-ray	7	4	3	7	3	0
Nursing	105	5	100	52	2	50
Laboratory	9	5	4	9	5	4
Dietary	24	4	20	18	2	16
Housekeeping	28	14	14	21	10	11
Plant operation	10	10	0	7	7	0
Laundry	10	2	8	10	2	8
Pharmacy	2	1	1	2	1	1
Outpatient department	7	2	5	7	2	5
Physical therapy	2	1	1	2	1	1
Central sterile supply	10	0	10	10	0	10
Physicians:						
Obstetrics	5	5	0	2	2	0
Surgery	20	20	0	10	10	0
General practitioners	20	20	0	10	10	0
Others	7	7	0	3	3	0
OTHER AMBULATORY PERSONS						
Volunteers	5	--------	--------	5	0	5
Visitors	20	--------	--------	20	10	10
Others (Sales, service)	10	--------	--------	10	10	10
Outpatients	20	--------	--------	20	10	10
Total	341	--------	--------	243	94	149
HOSPITALIZED PATIENTS						
Inpatients (80 percent of bed capacity)	120	--------	--------	120	--------	--------
Total	461	--------	--------	363	--------	--------

Figure 10.—Estimated occupancy for 150-bed hospital.

Shielding

By utilizing the principles outlined in this project, any degree of protection from fallout radiation, commensurate with the community's civil defense plan, can be incorporated in the hospital design. The shielding requirements for a particular hospital should be evaluated by the local authorities on the basis of its location with respect to probable target areas, direction of prevailing winds, potential for evacuation, and similar civil defense considerations.

For this study project, a radiation protection factor of 1,000 was adopted for the protected unit. According to present estimates, this would generally be adequate for the heaviest fallout areas. To achieve this degree of protection, the exposed wall construction should be equivalent to a mass thickness of 315 pounds per square foot (about 26 inches of concrete) and the roof 230 pounds per square foot (about 20 inches of concrete). If a smaller shielding value is selected, less thickness of wall and roof construction would be required. Since the requirements other than shielding (that is, mechanical, electrical, and architectural) will be the same for any degree of fallout protection, it is readily apparent that the protection capability is controlled by the amount of shielding provided. Because the small increases in mass thicknesses needed to provide higher degrees of shielding are comparatively inexpensive, the additional cost of better protection from fallout is insignificant.

For appropriate shielding design information, the hospital architects and engineers should consult the "Engineering Manual—Design and Review of Structures for Protection from Fallout Gamma Radiation."[1]

A vital factor in obtaining a reasonably uniform shielding value throughout the protected unit is to plan the area with as few openings to the outside as possible. Doors, windows, stair towers, elevator shafts, and similar large openings are difficult to protect efficiently. A circuitous entrance pattern or maze will reduce radiation penetration (although not to the same extent as a direct closure), but it hinders traffic flow. Direct closures of exterior wall openings by temporary baffle walls or massive doors, on the other hand, can be made as effective as the basic wall construction without affecting traffic in any way.

Since efficient traffic patterns are a functional requirement in hospital planning, the use of direct closures of exterior wall openings is recommended. Temporary baffle walls are more practical, from an economic point of view, when a high degree of shielding is specified. They, therefore, are used in this study project. Heavy doors would be more suitable, however, if the specified radiation reduction factor were low.

The elevator and stair shafts are removed from the protected unit without sacrifice of vital hospital functions, thereby eliminating the need for any protective measures for these elements.

Sleeping

On the basis of an 80 percent average occupancy rate, it is assumed that this hospital would have a census of 120 patients. Since approximately 10 percent of a hospital's patient population is critically ill, these patients would need intensive nursing care during the civil defense emergency period. Single cots are provided for these critically ill patients in the recovery room of the surgical department, where adequate intensive nursing facilities are available. The remaining 108 patients would be assigned to double-deck cots dispersed throughout the surgical and obstetrical suites, as shown on figures 11 and 12.

A small room or two rooms should be available for use as an isolation area in case one or more patients present symptoms of a contagious infection. The labor rooms in the obstetrical suite or perhaps one of the operating rooms would be suitable for this purpose.

Although this project did not require a study of the operational aspects of a hospital shelter, it was necessary to consider various operational assumptions in order to determine requirements for space and other hospital functions. For instance, in order to provide for the activities in the shelter during the fallout emergency period, it is assumed that approximately 32 administrative personnel would be required. Since this staff would be on call around the clock, it is recommended that they be assigned permanent spaces in double-deck cots. All other nonpatients would be organized on a three-shift-per-day program of work-rest-sleep and three persons would be assigned to

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[1] Copies may be obtained from the Office of Civil Defense, Department of Defense, Washington 25, D.C.

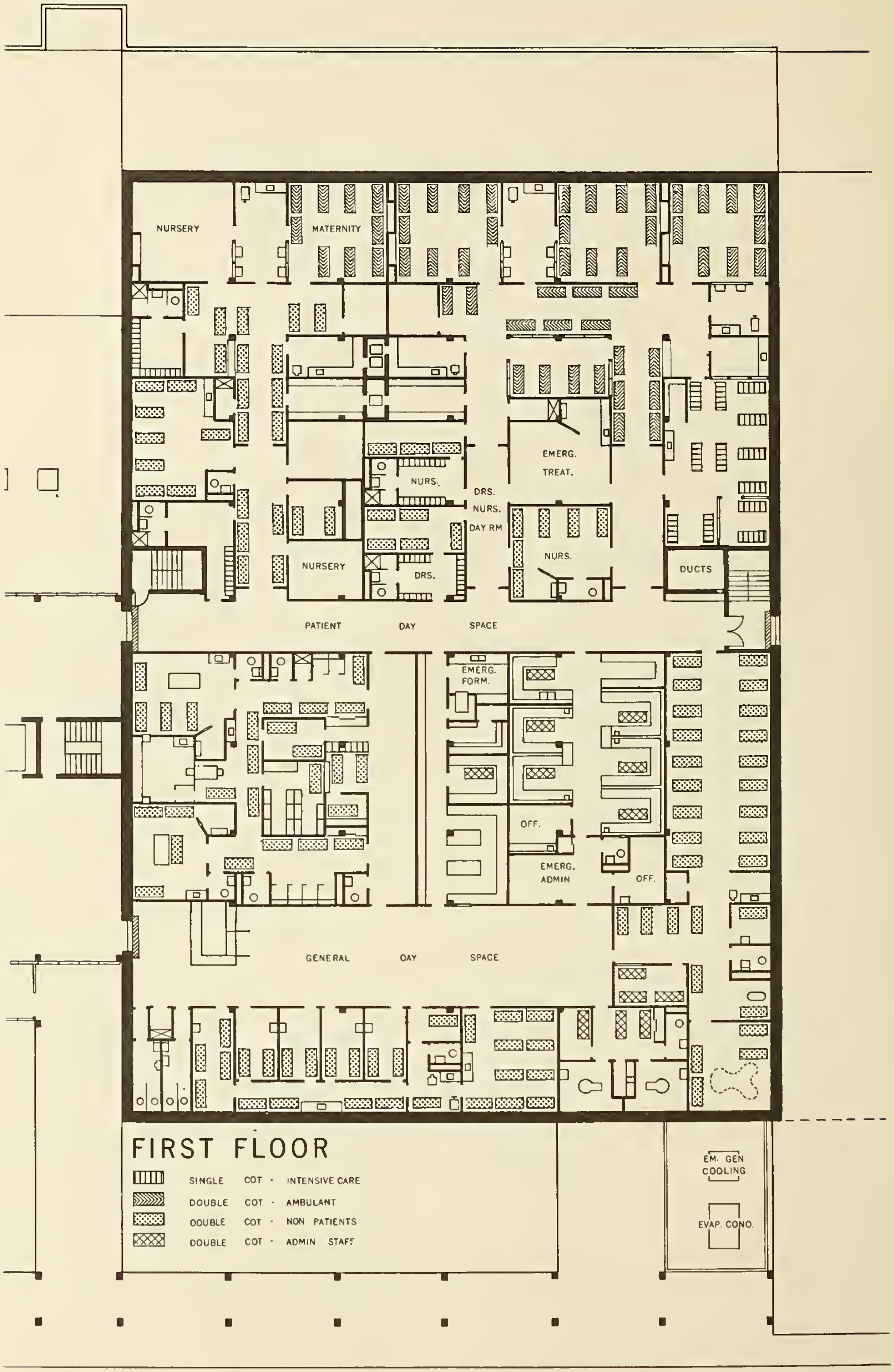
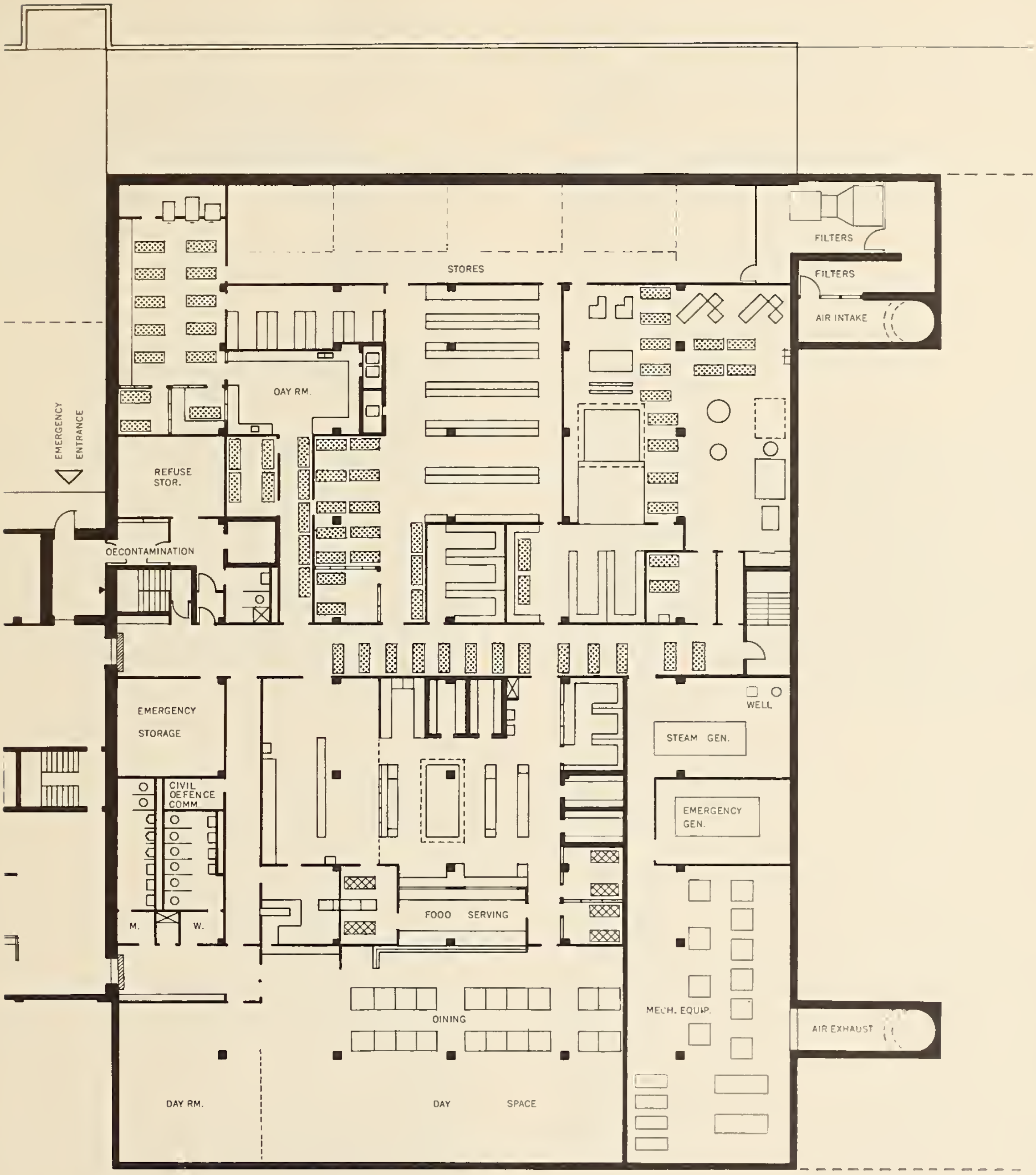


Figure 11.—First floor: sleeping arrangements during emergency showing the suggested cot distribution for maximum utilization of the first floor of the protected unit. Approximately 750 accommodations are shown here and on figure 12.



GROUND FLOOR

Figure 12.—Ground floor: sleeping arrangements during emergency showing the suggested cot distribution for maximum utilization of the ground floor of the protected unit.

each double-deck bunk unit for sleeping purposes. With this arrangement, one-third would be sleeping, one-third would be assigned to a work detail attending to patients and keeping the shelter in order, and the remaining third would be on off-duty status in the day space. This would eliminate the "hot bunk" problem without requiring an excessive number of sleeping accommodations.

Bedding (a sheet or unlined sleeping bag) and a number of indispensable personal hygiene items in a kit would be furnished each occupant.

Food

Since the dietary department, including food storage, is in the protected unit, all food reserves in the hospital at the beginning of the alert would be available during the civil defense emergency. Under an average hospital's routine purchasing policy, this stock of food supplies rationed to the shelter occupants at subsistence levels might last as long as a week. This means that for disaster conditions, prepacked food rations would then have to be furnished for another week. Cooking should be kept to a minimum, being limited to soups and beverages warmed on the electric cooking appliances.

For maximum utilization of working personnel and facilities within a normal three-meals-per-day schedule, food can be served every 6 hours around the clock, as indicated in the shelter operational chart, figure 13. Except for bedridden patients, cafeteria-style serving lines using single-service paper plates and cups are recommended if sufficient water is not available for washing dishes.

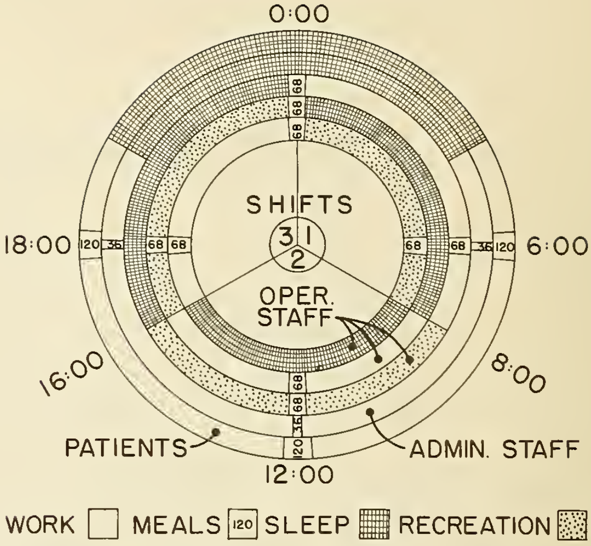


Figure 13.—Operational schedule of shelter activities showing a suggested routine for the daily activities of the shelter inhabitants based on dividing the day into three 8-hour shifts.

ELECTRIC POWER

Electric service for a protected hospital of the type described herein operates in the same manner as for an ordinary nonprotected hospital. Occasional interruption of the utility service is expected for any hospital during the normal course of time and events. An emergency electric service, usually of limited capacity, is required for all hospitals to assure continuity of critical functions within the hospital. Many public utility service facilities will not be protected against fallout radiation; hence it must be assumed that such services will not be available during such an emergency. Accordingly, emergency electric generating facilities must be installed in the protected sections of the hospital and must be of sufficient capacity and have the correct electrical characteristics for operation of the selected lighting, pumps, fans, and other essential motorized equipment, as well as for cooking or warming food. A supply of fuel and lubricants for operation of the generating unit at full load continuously for not less than 2 weeks should be provided.

This hospital is divided into two principal sections: one section protected against fallout radiation, the other an unprotected section. During an ordinary interruption of the utility service, the emergency service would be connected in both the protected and the unprotected sections. During fallout conditions, the emergency service would be manually disconnected from the unprotected section. The emergency electric capacity thus saved could then be applied in the protected section to operate additional equipment that is not emergency-operated during an ordinary short-time interruption of the normal utility service.

For this particular design, it is estimated that the emergency power capacity required for lighting and for operation of essential equipment in the protected section alone, under fallout emergency conditions, would be 250 kilowatts. This is less than the estimated 301 kilowatts needed for both the protected and unprotected sections during an ordinary short-time interruption of the normal utility service.

In both the protected and the unprotected sections of the hospital, the selected lighting circuits should be automatically connected to the emergency service when the normal service is interrupted, but motors (except fractional horsepower motors) should be arranged for manual starting in such a sequential manner so as not to overload the generator. Overload protection of feeders should be so provided that an internal fault in one section of the hospital will not cause an interruption of service in the other section.

It is recommended that consideration be given to providing circuitry to permit convenience of alternately operating certain equipment and also for possible future connection of additional generating capacity.

MECHANICAL SYSTEMS

The primary consideration in the design of the mechanical systems is to provide for the normal requirements of the hospital and to incorporate those features necessary to accommodate the disaster conditions resulting from a nuclear explosion. To accomplish this, it is necessary to deviate slightly from the conventional designs of several systems in the protected unit. However, these deviations in no way detract from normal service, and in some respects improve the service.

The utilities and services discussed in this section are: plumbing, water supply, fire protection, heating, air conditioning and ventilation, and refuse and garbage disposal.

As previously described, the hospital is divided into two main areas, an unprotected area and a protected area, separated from each other by an elevator tower. The unprotected area houses the administration and nursing functions and the protected area houses the adjunct facilities, including such service areas as laundry and kitchen.

Since the unprotected area would be evacuated at the time of the emergency and would have no function in the shelter plan, no special mechanical design considerations are involved. The details of such design are well established and are not discussed here except to point out several features pertinent to the overall plan. The main boiler plant, including the incinerator, which serves the entire hospital facility is located in the unprotected area. Individual piping systems are continuous throughout the entire facility, but during an emergency it will be necessary to shut off the piping systems in the unprotected area and isolate them from the shelter. To facilitate this shutoff, the piping systems are grouped at the point where they pass from the unprotected area to the protected area and are valved on the protected area side. Because of the physical separation of the two hospital areas by the elevator tower, the use of individual air-conditioning systems for each area is preferred. Separate systems reduce the possibility of infusion and contamination of the air in the protected unit by the air from the unprotected area. The cooling tower that serves the unprotected area and the house tank for domestic water service are located at the top of the elevator tower. The entire air supply for the unprotected area enters through a stack on the roof at one end of the building, as remote as possible from the boiler, incinerator, and ventilation exhaust stack unit that is located on the roof at the opposite end of the building.

The protected unit of the hospital will be used as the shelter during the emergency. A space analysis indicates that this area can accommodate approximately 750 persons during this period. The deviations from conventional design necessary to counteract the possible contamination of outside water and air and to insure adequate disposal of all wastes are discussed in detail under the individual mechanical systems affected.

Plumbing

The plumbing system is designed for normal hospital operation, with the assumption that a public sanitary and storm sewerage system and a public water supply are available. As previously mentioned, the water, sewer, gas, oxygen, and other piping systems are grouped and valved at the point where they enter the protected area, to permit quick cutoff from the unprotected area upon warning of an emergency.

To reduce to a minimum the number of openings through the roof, the individual vent lines serving the plumbing fixtures in this area are connected into two vent headers. Each of these headers has one vent, to the outside, which is provided with a hood to prevent any fallout from dropping into the vent.

Because the municipal sewage disposal facilities may be damaged or may not be protected against radiation resulting from fallout, and therefore may not be manned or in operation during the emergency, a sewage sump and ejector system is installed to provide a positive means of removal of sewage from the building (fig. 14). The discharge from this sump is carried to the street sewer line. Should the street sewer become blocked, a bypass is provided which will permit discharge of the sewage to the ground surface outside the building. During normal operations, the ejector system is not used and the bypass line is capped.

A check valve and shutoff valve are installed in the normal building drain. The fresh air inlet at the house trap pierces the basement wall underground and then runs vertically to the atmosphere where it terminates with a gooseneck attachment above ground.

Where the site permits gravity flow of sewage to the outside ground surface, a bypass without ejector would suffice. However, the sewage sump and ejector would be helpful for disposal of waste where chemical toilets must be used. If a sewage ejector is required for normal operation, a bypass line for the normal building drain should be installed.

Rain water leaders serving the protected area are located on the exterior of the building. Interior leaders are not used because of the possibility of radioactive materials entering the leaders and creating a source of radioactivity within the shelter.

The number and type of plumbing fixtures used are those which would be designed for service on the basis of normal hospital operation. If the water supply is insufficient to permit the use of the standard fixtures, chemical toilets will be required. The waste from chemical toilets may be disposed of through the sewage sump ejector system.

The Office of Civil and Defense Mobilization has defined plumbing fixture requirements for mass public shelters. However, because hospital patient requirements exceed those of the healthy population, the following fixture criteria have been developed for hospital shelters:

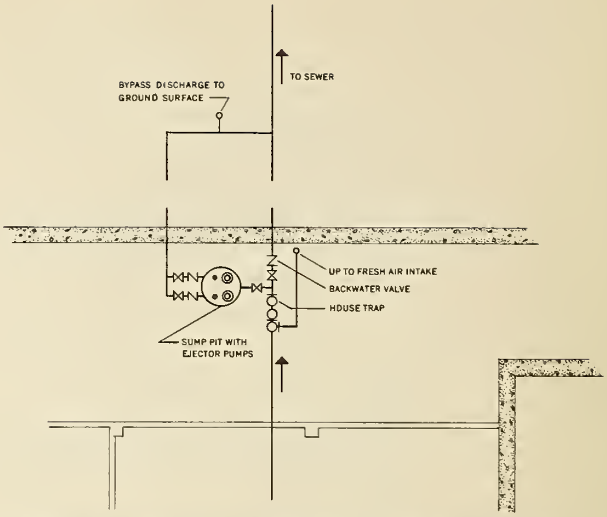

BYPASS DISCHARGE TO GROUND SURFACE
TO SEWER
UP TO FRESH AIR INTAKE
BACKWATER VALVE
HOUSE TRAP
SUMP PIT WITH EJECTOR PUMPS

Figure 14.—Plan arrangement of sewage ejector bypass for use during emergency.

Water closets	1 for each 25 patients and 1 for each 35 nonpatients
Lavatories	1 for each 35 persons
Shower baths	1 for each 60 patients and 1 for each 120 nonpatients

The number of water closets and lavatories provided in the protected unit amply meets the requirements for an anticipated population of 750 persons in the hospital shelter. The number of shower baths, however, is insufficient to meet the criteria, but this problem is solved by providing for the installation of a hose bibb and shower head in each janitor's closet over the floor-type receptor which can serve as the drain.

Water Supply

The design of the water distribution system is conventional, and is supplied by two services from public water mains and from a house tank in areas where water main pressure is unreliable or inadequate. A house tank is assumed to be necessary for this project.

Because of the possibility of radiological contamination of sources of public water supply, such as impounded reservoirs, rivers, and water sheds, and because of possible destruction or contamination of municipal distribution lines, it is essential that a reliable source of water, independent of the municipal system, be available during the emergency (fig. 15). Ground water, which is available in many parts of the country, offers a solution to the problem, since a well can be developed within the protected area.

According to established code, private well systems cannot be connected to the normal distribution system served by a public water supply. In this project, a pneumatic pressure system is used with the well and provision is made for quickly connecting the two systems at the time of emergency. This connection consists of a spool piece which can be inserted between blank flanges provided in each of the systems.

The well should have a capacity to produce a minimum of 25 gallons of water per day per person for drinking, cooking, and sanitary purposes. In addition, it should provide sufficient water for cooling the air-conditioning equipment and the emergency electric generator. The amount of water required for cooling the equipment will vary according to climatic conditions.

Where wellwater is available but not suitable for human consumption, the water may be utilized for sanitary and cooling purposes. In this event, storage must be provided for a minimum of 1 gallon of potable water per person per day for drinking purposes.

The potable water storage tank should be located preferably in the protected area and placed in series with the public water supply system. This produces constant circulation through the storage tank during normal operation which prevents stagnation and assures a supply of fresh water at the beginning of the emergency. Where a house tank is provided, it may serve as storage for potable water. To control the use of stored water during the emergency, a water line independent of the normal distribution system should be installed from the storage tank to a convenient point for rationing.

The storage of sufficient water for all purposes is impractical because of cost, space requirements, and difficulty of maintenance. If water is not available from the public system or from a well, it will be necessary to store drinking water, use chemical toilets, and provide air-cooling systems for the air-conditioning condensers and electric generator.

Heating

Boiler rooms are usually designed with large doors and windows to facilitate the removal of equipment and to provide light and ventilation. These openings make the boiler room a particularly hazardous area and untenable in case of radioactive fallout. For this reason, a source of heat must be provided for use during the emergency. Two methods for providing this heat merit investigation: (1) recovery of the heat produced by the diesel engine emergency electric generator or (2) a small emergency boiler.

Because of the construction characteristics of the protected area and its high density population, space heating is limited to the tempering of ventilation air during extreme winter conditions. It is assumed that the hospital functions during the emergency will be minimal, involving only care of patients, necessary surgery, and deliveries. As a result, sterilizing requirements will be minimal and may be handled by an electric sterilizer supplemented by the routine steam sterilizers, if needed. The hot water heating load will depend upon the availability of a water supply and may vary in different areas of the country. Where the

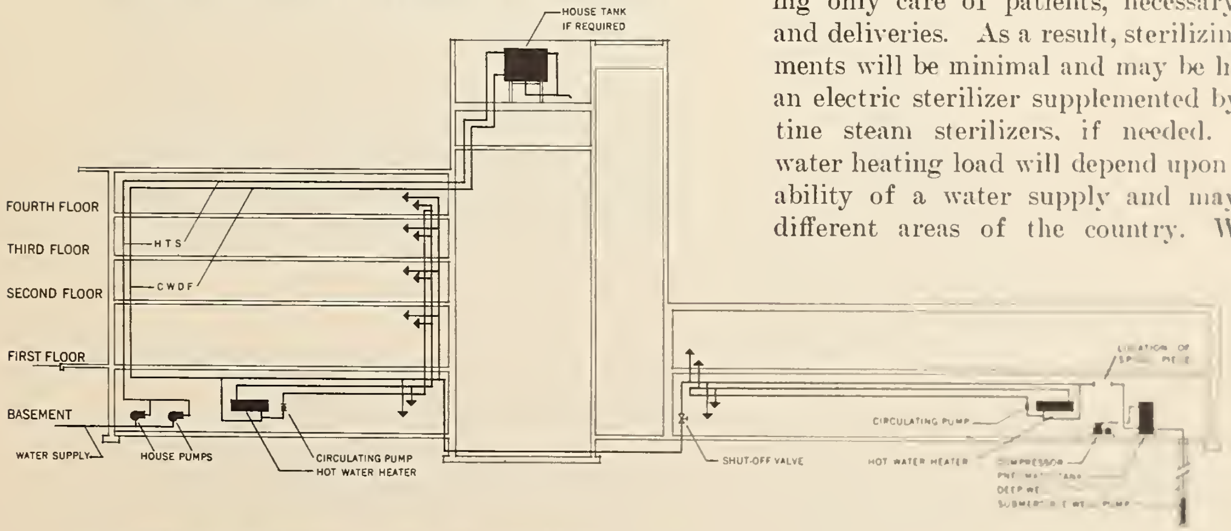


Figure 15.—Schematic diagram: domestic water distribution.

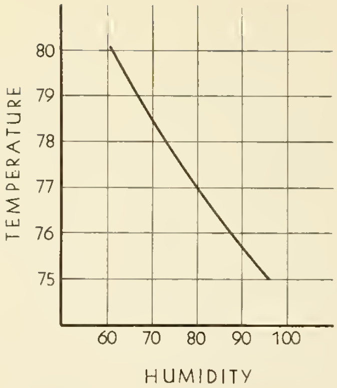


Figure 16.—Effective temperature chart showing the combination of temperature and humidity conditions represented by an effective temperature of 75 degrees.

water supply is limited, austerity must be invoked, and the boiler load will be considerably less than where a well source is available.

A study of the two methods of heating indicates that the installation of a small, high-pressure boiler in the protected area would be more economical, less complicated, and more readily adaptable for emergency hospital operation. Although the mechanical system may be designed for normal usage of this boiler, such an arrangement ordinarily will be uneconomical in utility and operation. For this reason, therefore, this high pressure boiler should be considered suitable only for emergency purposes.

Oil is recommended as the fuel for the emergency boiler because an ample supply can easily be stored for the emergency period, eliminating dependence upon an outside supply source. The oil supply for the emergency boiler and the emergency electric generator should be stored in one tank. The occasional power outages under normal operation, which should be anticipated, would require operation of the electrical generator and would provide some turnover of this oil supply. A single storage tank would facilitate closer supervision of the supply.

Air Conditioning and Ventilation

The air components for physical comfort and well-being with which we are primarily concerned, especially in a shelter having a high occupancy, are oxygen, carbon dioxide, and water vapor. However, consideration also must be given to odorous and pathogenic contaminants that occur in hospitals, and to chemical, biological, and radiological warfare agents that must be anticipated during disaster conditions.

Suitable levels of oxygen and carbon dioxide must be maintained at all times in the protected area. Based on the necessary activity in a hospital shelter, an estimated average of 0.9 cubic foot of carbon dioxide would be produced each hour by each occupant. An atmospheric concentration of 3 percent carbon dioxide is the maximum that a healthy person can tolerate without physical strain. Such concentration could be disastrous to some hospital patients. According to present estimates, the ventilation system for this protected unit could be shut down for a continuous period of 20 hours before the area attains the critical level of 3 percent carbon dioxide.

Bulk oxygen storage for hospital use is located adjacent to the protected area, and the main from this oxygen source enters the hospital in the protected unit. Should dangerous ventilation conditions occur in the hospital shelter, this oxygen supply could be used as a source of oxygen replenishment. Absorption and closed regenerative systems to maintain the desired oxygen and carbon dioxide levels are considered to be too complicated and expensive to install in hospitals.

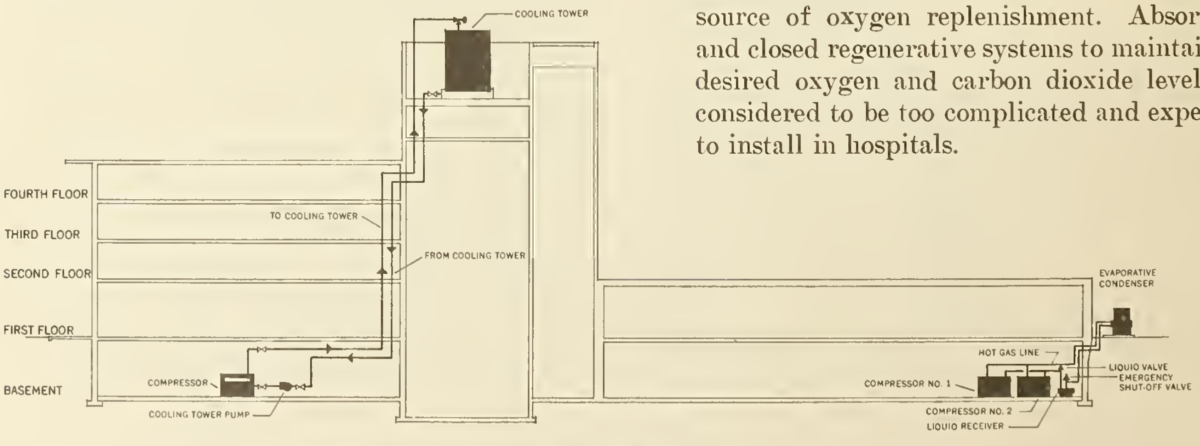


Figure 17.—Schematic diagram: air conditioning heat removal systems.

Suitable levels of oxygen and carbon dioxide are best maintained by the introduction of fresh outdoor air into the area by means of air conditioning. Minimum outdoor air ventilation rates to maintain proper levels of oxygen and carbon dioxide are dependent upon the per capita space allotment of the area involved. The Office of Civil and Defense Mobilization has established 3 cubic feet per minute per person as the minimum ventilation rate for mass public shelters. Because of the physical condition of many of the occupants of a hospital shelter and because of the ventilation requirements for certain clinical areas that may be active during an emergency, a minimum rate of 7 cubic feet per minute per person is recommended for hospital shelters. This higher ventilation rate provides for odor control and also assists in maintaining sufficient air pressure within the protected area to prevent infiltration of contaminated outdoor air. If the outdoor air supply is limited to less than 7 cubic feet per minute, consideration should be given to designing the ventilation system with space for insertion of activated charcoal filters for odor control.

Temperature and humidity must be maintained within reasonable comfort levels, particularly for the benefit of hospital patients. Effective temperature, which is an arbitrary index representing the effect of warmth or cold felt by the human body, is the best available index of ambient atmospheric conditions in relation to the physiological response of man. An effective temperature not to exceed 75 degrees is recommended for hospital shelter areas. This provides a range of temperatures and humidities somewhat above normal design practice for comfort but well within tolerable limits (fig. 16).

Because of the construction characteristics of shelters, the population density anticipated, and the physical condition of many occupants, year-round air conditioning will be necessary for hospital shelters in most areas of the country.

Design Features

The air-conditioning and ventilation system is designed for normal hospital operation, but modification of the design is required to meet the conditions anticipated during an emergency.

The air-conditioning system consists of a central compressor plant and water chillers, with an evaporative condenser for dissipation located at ground level outside the protected area (fig. 17). Individual conditioning units consisting of a fan and filter; preheat, cooling, and reheat coils; and a humidifier are used for each hospital department. In the units serving the kitchen and laundry departments, the cooling coils are installed primarily for use during the emergency and are valved to permit a cutoff when not required during normal operations.

Outdoor air is delivered to each unit by a duct system from the central supply air plenum chamber. This outdoor air is filtered at the main air intake duct before it is delivered to the individual conditioning units. The filters used in each of the individual units for final filtering are selected according to the air quality required by the department served. For example, the units serving the operating, delivery, and recovery rooms require filters capable of removing 90 to 99 percent of all particulate matter in the size range of 1 to 5 microns. Such areas as the laundry and the waiting room in the outpatient department are amply served by medium-grade filters with efficiencies of 60 to 90 percent in the same particle size range.

All duct systems are equipped with modulating dampers that permit varying the amounts of outdoor and recirculated air in each department during normal hospital operation (fig. 18). This applies particularly to the operating and delivery rooms where recirculation of air is permitted when these rooms are not in use (fig. 19). In addition, these dampers are so arranged that they can be reset from a central control point to deliver only the predetermined quantity of fresh air alloted to each area during an emergency.

Chilled water for each unit is supplied by the central refrigeration system located in the protected area. Steam is supplied by the main boiler plant to each unit during normal operation and by the standby boiler in the protected area during an emergency.

Since there is ample headroom above the finished ceilings, the conditioning units are placed on large platforms in this space, thus providing room for personnel to move around the equipment to service it. Without this headroom, these units would have been located in an equipment room in each area. The use of individual conditioning units is considered good

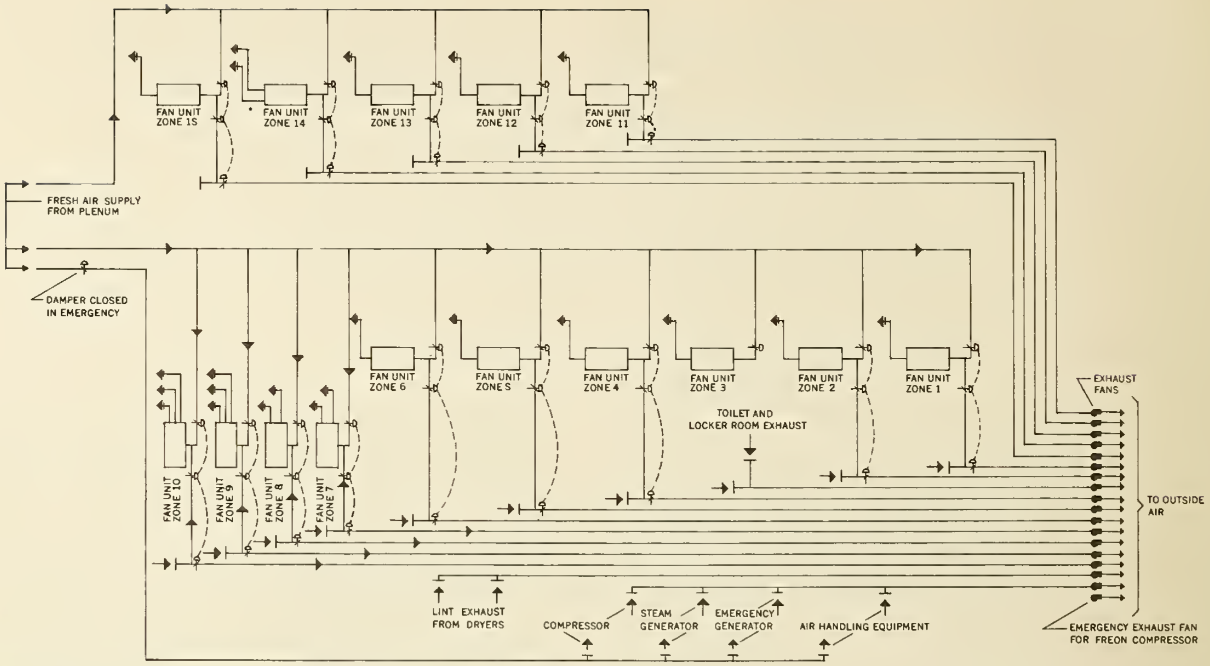


Figure 18.—Ventilating and air conditioning flow diagrams.

design for hospital systems and adequately fulfills the emergency protection requirements. Individual units have several advantages: (1) greater flexibility of use can be provided; (2) control systems are less complicated; (3) temperature fluctuation in transmission from the equipment to the conditioned area is reduced; and (4) only one area is affected by a breakdown.

Each department is served by an individual exhaust fan that operates in conjunction with the department air-supplying unit to maintain a proper air balance. The surgical and obstetrical suites are served by several supply and exhaust systems to provide flexibility during periods of partial use of these areas.

All exhaust fans are located in one large machine room from which they discharge into the common exhaust plenum and the central exhaust stack (fig. 20). This arrangement facilitates maintenance of the fans and provides a negative pressure in the parts of the exhaust duct system that supply the hospital.

Outdoor air for the entire protected area enters through a freestanding tower located approximately 25 feet from one end of the building. All exhaust air from the protected area is discharged from a similar tower located at the opposite end of the building. The two towers are separated as far as practicable, to minimize the possibility of the exhausted air entering the fresh air intake (a common fault in planning). The exhausts from the standby boiler and the emergency electric generator are piped underground to the base of the exhaust tower and then vertically within the stack to be discharged at a point near the top. The two towers extend 12 feet above the roof of the pro-

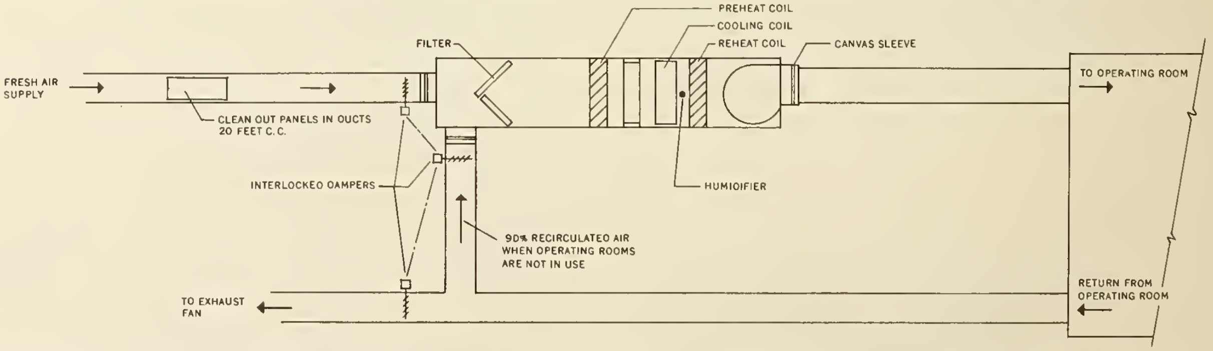


Figure 19.—Air conditioning for operating rooms: schematic arrangement of air-handling unit, controls, and duct system.

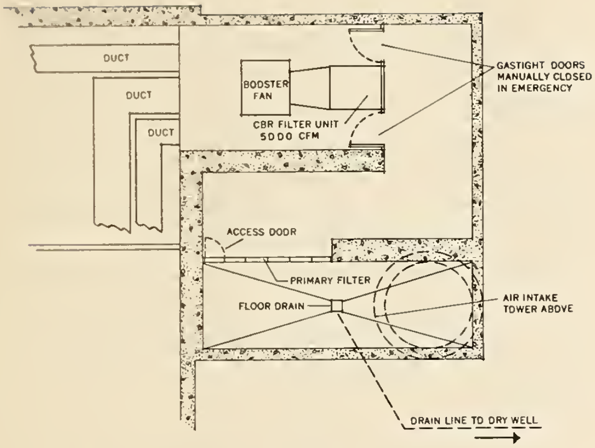


Figure 20.—Fresh air intake showing filter arrangement at air intake to the protected unit.

tected area to prevent any drift from the roof entering the stacks. Each tower is equipped with hoods to prevent vertical settlement of fallout in it. The hood for the outdoor air-supply stack also induces a change in the airflow pattern which helps to prevent large particles of dust from entering the stack. The fresh air intake, which to some extent dictates the location of the exhaust outlet, is not placed within the structure because of the space required for the additional radiation barriers necessary to protect the interior of the building from the inlet opening and from the accumulation of radioactive fallout on the filter beds.

The air entering the fresh air tower travels downward to the bottom of the stack and then horizontally through a settling chamber to the primary filter bed (fig. 21). A floor drain, located in front of the filter bed, facilitates cleanup of the settlement chamber. This floor drain is piped to a dry well 25 feet from the building and has sufficient ground cover to insure protection against any radioactive material that may be washed into it. The filter bed is made up of medium-grade filters, 80 percent efficient according to the National Bureau of Standards "Dust Spot Method of Testing." (ASHVE Transactions, Vol. 44, p. 379, 1938.) These filters will remove all significant radiological fallout from the outdoor air during the emergency. High-velocity filters, with a face velocity of 600 feet per minute, were selected to reduce the size of the filter bed. A concrete protective barrier is interposed between the filter bed and the opening to the shelter.

Although fallout protection is emphasized, it is considered advisable to install a chemical, biological, and radiological (CBR) filter unit for protection against these agents. This filter unit is located between the primary air filter and the shelter area. A gastight door in the main air passage would be closed during emergency to divert all incoming air through the CBR unit. The unit can handle 5,000 cubic feet of air per minute, which would provide approximately 7 cubic feet per minute for each of the anticipated 750 occupants in the shelter. Because of the size of the CBR unit, a hatch is provided in the roof of the air-intake chamber, through which the unit can be removed if necessary.

Under disaster emergency conditions, when it becomes necessary to limit the outdoor air supply to 5,000 cubic feet per minute for the protected area, the quantity of air mechanically exhausted would be reduced in order to maintain an air pressure within the area. To accomplish this, all exhaust fans except those serving the toilet rooms, the boiler room, and the decontamination area will be shut down. All fan discharge ducts, with the exception of those noted above, discharge into a section of the exhaust plenums that may be cut off from the main exhaust stack by an airtight door. This arrangement eliminates any exfiltration of air through these fan systems. Barometric controls for emergency use are installed on the exhaust fans that remain in operation. These controls are set to maintain a 0.5-inch water gauge pressure within the protected area during the emergency. A backdraft damper is installed in the wall between the kitchen and the standby boiler room to provide combustion air for the boiler. Combustion air for the emer-

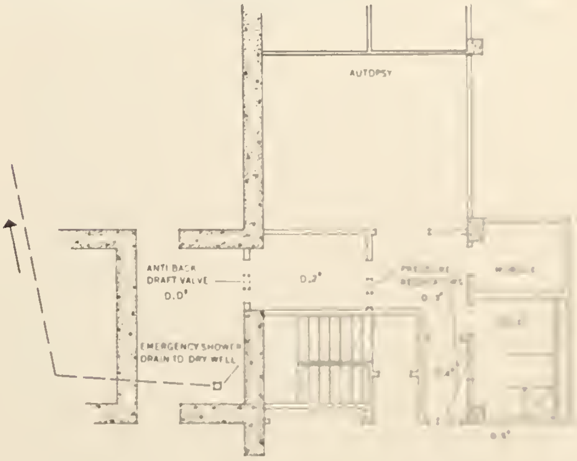


Figure 21.—Plan of decontamination unit showing relative pressure differences to prevent entry of contaminated air into the protected unit.

gency electrical generator is piped direct to the engine from the main air supply.

The morgue and autopsy area, as previously noted, is used for decontamination purposes (fig. 21). The passageway through this area has been compartmentalized to provide a series of airlocks between the protected area and the outdoors. A fan having a 400-cubic-feet-per-minute capacity is installed above the door that leads from the shelter into the first airlock. This fan, to be used for emergency only, will exhaust air from the protected area into the decontamination area. The doors connecting the airlocks are equipped with dampers to provide a progressively lower air pressure in each airlock, with final discharge to the outside. This arrangement will assure that no contaminated outdoor air can enter the protected area.

Refuse and Garbage Disposal

Provision for the disposal of refuse and garbage must be carefully planned. Garbage, heavy cartons, bottles, and cans pose the greatest problem. Where an ample supply of water is available, garbage grinders are effective for food waste disposal. An incinerator is not recommended because it involves duplication of other available equipment, requires considerable combustion air, and does not dispose of bottles and cans. In this project the autopsy room, which is within the area used as the decontamination entrance, is used as a rubbish storage room. This room is selected since it will not be in use, is located away from the normal circulation area of the shelter, and is convenient to the only doorway in use during the emergency. Periodically, the accumulation of waste can be removed to the outside, if necessary.

Fire Protection

Fire protection methods in both areas are conventional, consisting of a standpipe system and hose stations generally supplemented with water-type fire extinguishers. Carbon dioxide extinguishers are provided in the boiler room, operating suite, delivery suite, emergency generator room, kitchen, and laundry. If the water supply is safe and adequate, the standpipe would be kept active during the emergency period; otherwise, fire protection would depend upon the available supply of fire extinguishers.

COST OF PROTECTION FOR PROTOTYPE HOSPITAL

A major objective of this study is to demonstrate that protective measures against fallout can be incorporated in the planning and construction of hospital buildings at reasonable cost. Detailed cost figures for many items are singularly elusive, and they tend to be particularly so in a study where comparative costs are determined without benefit of definite contract prices. However, in order to establish some measure of the cost for fallout protection, an estimate was made of the additional cost of constructing the prototype hospital incorporating the described protective measures. These estimates were based on early 1961 costs in the New York City area and could be converted to approximate costs in other geographical areas by using an appropriate comparative building cost index.

Cost of 150-bed hospital (without protection)	[1] $3, 750, 000
Fallout protection	136, 285
Protection against chemical and biological contaminants	5, 950
Moderate blast protection (15 psi overpressure)	72, 325
Additional cost to incorporate protection measures	214, 560

[1] Cost figure based on average cost of hospitals of similar size built under Hill-Burton Program during 1960.

From these figures, it can be seen that the cost of constructing the prototype hospital incorporating only the radiation-fallout protection measures described herein would be approximately 4 percent more than the cost of a similarly planned, completely air-conditioned hospital of conventional construction.

The low additional cost can be attributed to the following factors:

(1) Little additional space is required solely for protective purposes. Only space for the storage of emergency supplies (food, cots, and similar items), civil defense communications, emergency boiler, air intake and filter, and air exhaust would be in excess of that required for normal hospital functions.

(2) Little additional equipment is required solely for protective purposes because a hospital is well supplied with mechanical and electrical equipment that is readily convertible for shelter use.

(3) The hospital areas involved permit a high degree of efficiency for providing maximum shelter capability.

PROTECTED ADDITION TO AN EXISTING HOSPITAL

A satisfactory nationwide program of protected health facilities obviously cannot be achieved in a reasonable time by the construction of new protected hospitals. Therefore, the role of the existing hospital becomes very important. Various methods of applying the

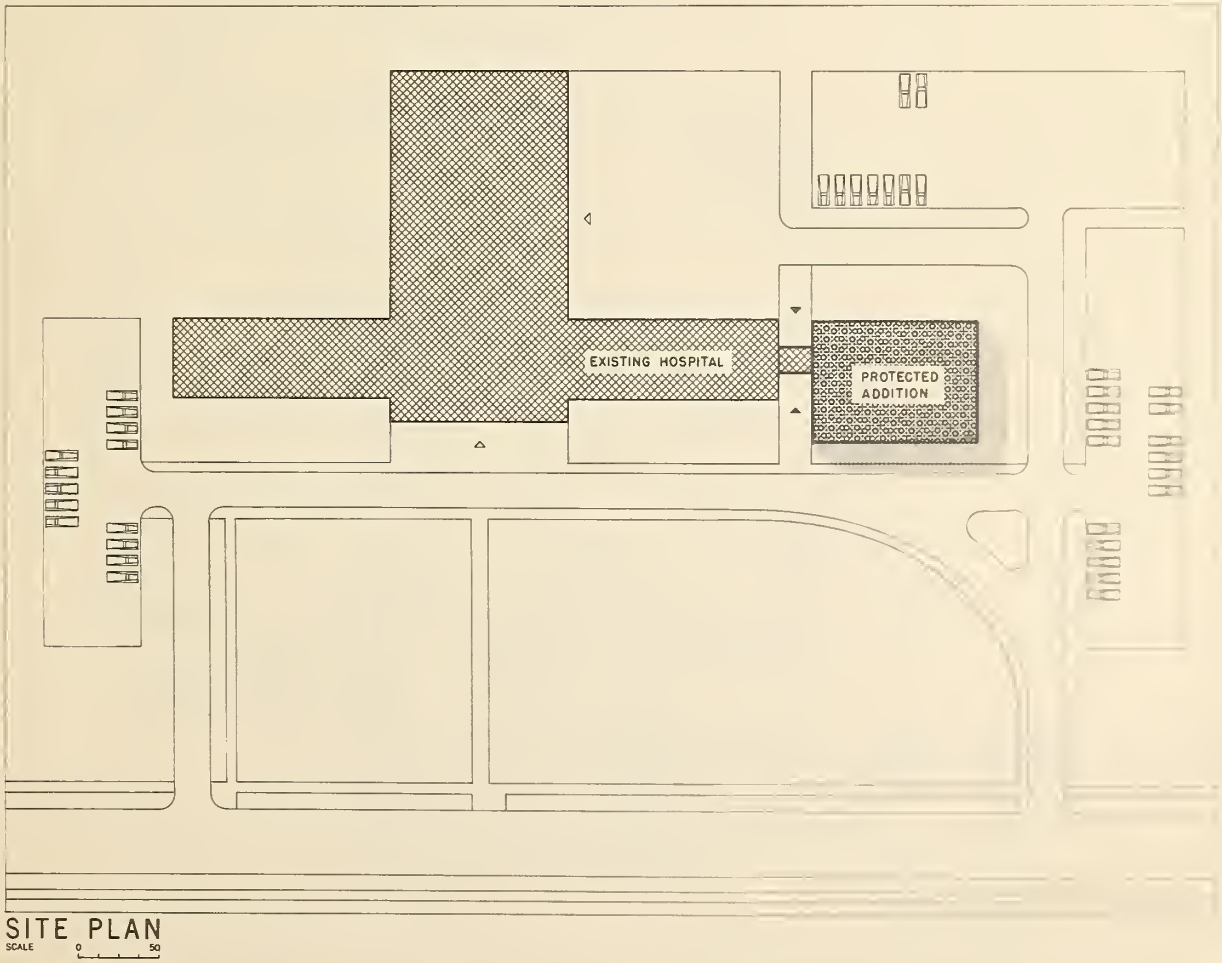
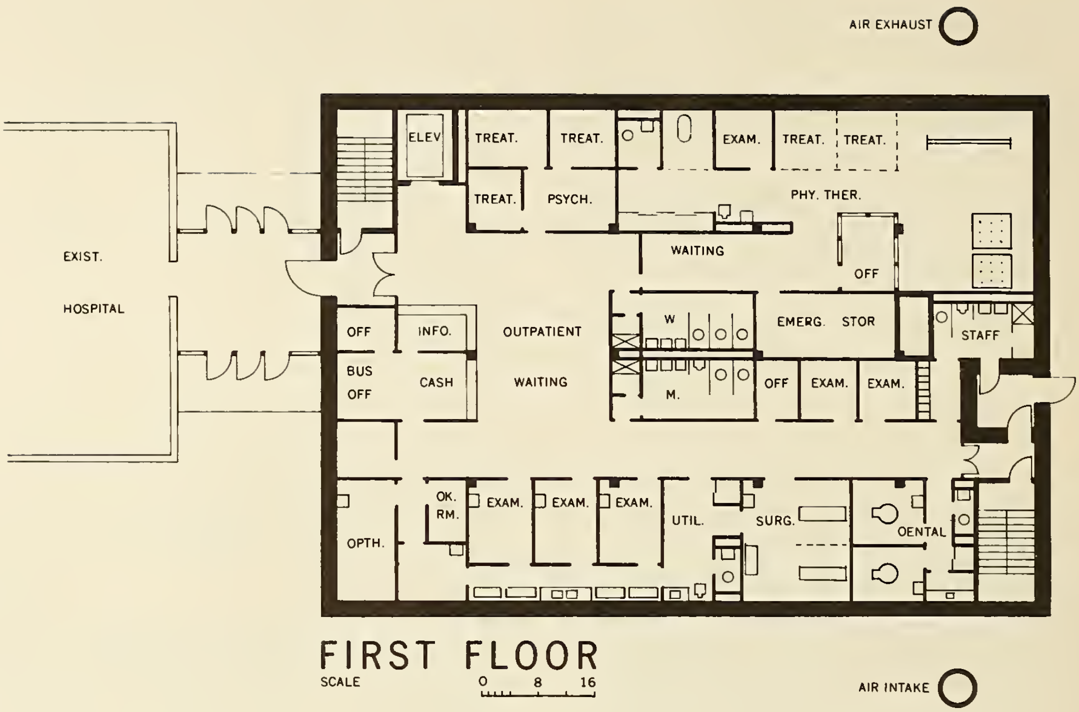
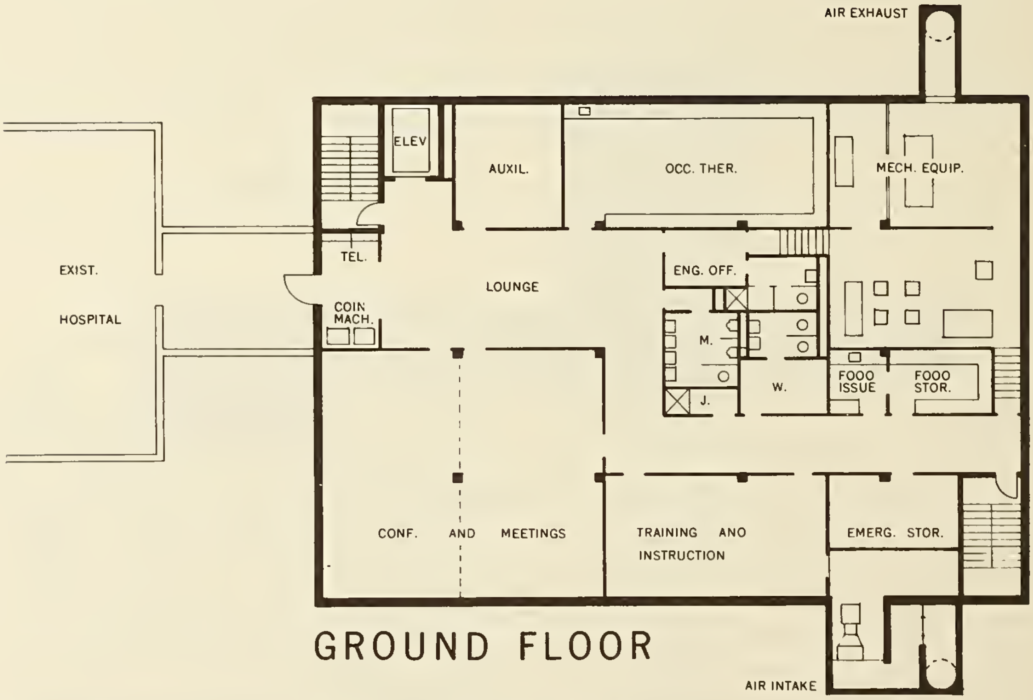


Figure 22.—Protected addition to an existing hospital: site plan.

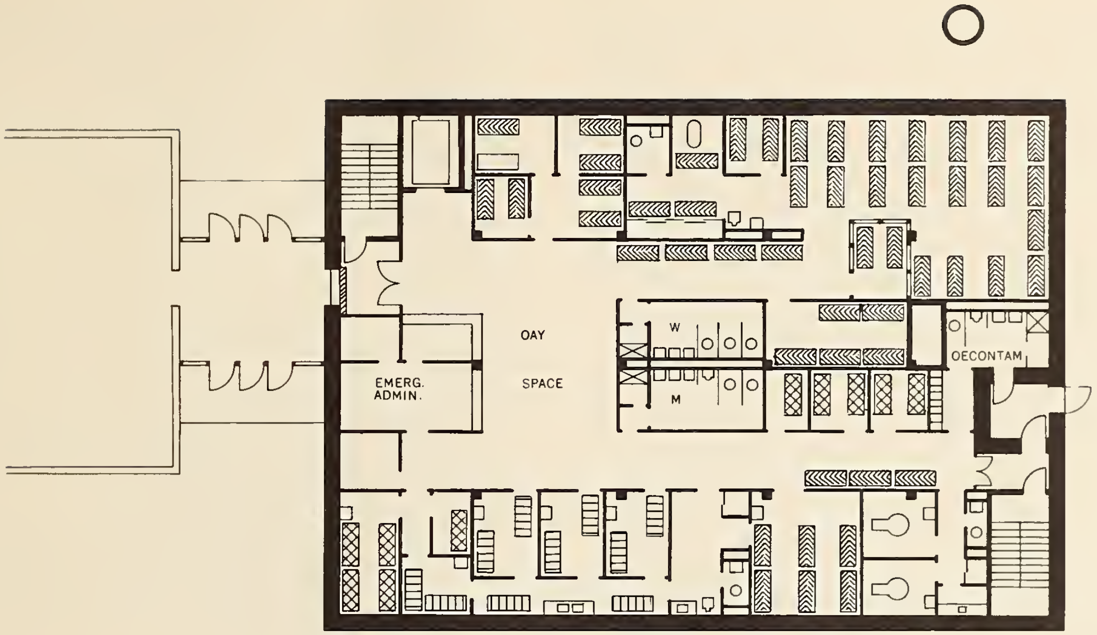


FIRST FLOOR



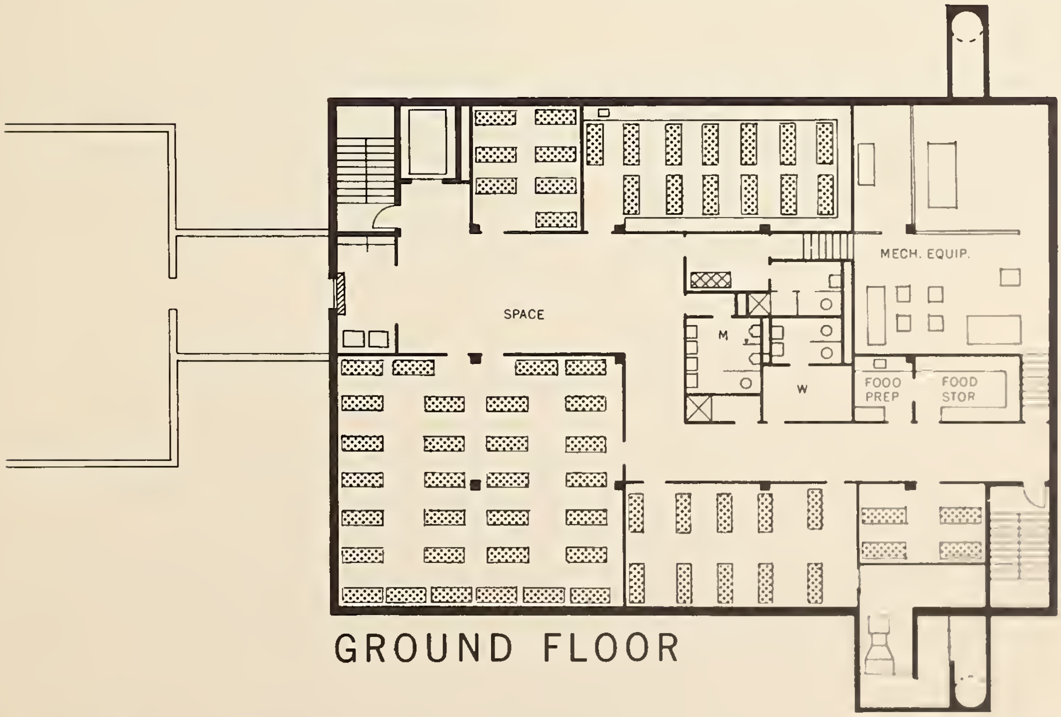
GROUND FLOOR

Figure 23.—Protected addition to an existing hospital: floor plans.



FIRST FLOOR

▥ SINGLE COT - INTENSIVE CARE
▨ DOUBLE COT - AMBULANT
▒ DOUBLE COT - NON PATIENTS
▩ DOUBLE COT - ADMIN. STAFF



GROUND FLOOR

Figure 24.—Protected addition to an existing hospital: sleeping arrangements during emergency showing the suggested cot distribution, accommodating 363 persons.

principles of protective construction for the maximum benefit of existing hospital plants were studied.

Because of the type of construction of existing hospitals, age of the buildings, and other factors, it would be very difficult to utilize any portion of the existing buildings as shelters with any degree of success, either functionally or economically. It would be possible, however, to plan a protected addition to an existing hospital by using the data developed for the prototype hospital described.

Since the planning requirements for each addition would vary with each hospital, it is difficult to propose specific planning recommendations. Whether an addition could be designed with all the requisites for fallout protection with the same efficiency as a new hospital would depend on the kinds of services to be located in the addition. Some hospital services are not readily adaptable to shelter use; where such services must be located in a protected addition, it is obvious that a low degree of shelter efficiency will result. In some instances, the need for shelter space may exceed the space available in the addition. In this case, areas such as meeting rooms and training facilities, which usually are difficult to justify on a hospital's budget, might be acceptable when designed to be used in connection with the shelter program.

The services selected for inclusion in the prototype addition to an existing 150-bed general hospital are those commonly lacking or outgrown in many hospitals. They also happen to be highly efficient from a shelter point of view, and because of this, the protected unit is probably as small as can be devised to house the scheduled peak population of 363. In all probability, if other types of hospital services are used, a larger area will result.

The plan for this addition is a windowless structure of one story above grade and a full basement. The first floor contains a rather complete outpatient department and a physical therapy department. The basement contains several meeting and instruction rooms, an occupational therapy room, mechanical equipment room, and storage facilities for the civil defense supplies and equipment. (See figs. 22, 23, 24.) The shielding, sleeping, electrical, and mechanical features of the protected addition are essentially similar to those discussed in the prototype fallout-protected hospital.

The following tabulation gives the relative cost figures for constructing the addition to a 150-bed general hospital with various protection factors as outlined:

Cost of addition to 150-bed hospital (without protection)	[1] $500,000
Fallout protection	65,145
Protection against chemical and biological contaminants	5,650
Moderate blast protection (15 psi overpressure)	48,940
Additional cost to incorporate protection measures	119,735

[1] Cost figure based on average cost obtained from Hill-Burton Program studies.

From these figures, it can be seen that the cost of constructing an addition with only radiation fallout protection measures would be approximately 13 percent more than the cost of a similarly planned unit of conventional construction.

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